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Effects of Boron, Copper, and Zinc on Leaf Composition and Yields of Corn

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OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
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CONTENTS

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AGDEX $\frac{111}{532}$

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J. BENTON JONES, JR.[1]

INTRODUCTION

The need for the application of micronutrients, particularly boron, copper, and zinc, for corn has not been well established in Ohio. Recent interest in these nutrients among Ohio farmers is due to an increasing awareness of the importance of micronutrients for plant growth and the desire of farmers to achieve maximum yields by eliminating possible nutrient deficiencies.

Widespread symptoms characteristic of boron, copper, or zinc deficiencies in corn have not been evident in Ohio. Copper deficiencies have occurred only in muck soils in northwest Ohio. Visual boron deficiency symptoms have not been reported.

Experiments conducted in Ohio between 1936 and 1941 showed no significant crop responses to the use of micronutrients (4). From 1941 to 1960, no research was conducted in Ohio on the use of micronutrients for corn.

In 1964, a Plant Analysis Laboratory was established at the Ohio Agricultural Research and Development Center to provide farmers with a means of evaluating the nutrient status of growing crops. Determination of the concentration of boron, copper, and zinc is included in a standard plant analysis. In a summary of results of plant analyses in 1964 (3), 5 percent of the corn samples analyzed may have been deficient in zinc but none were deficient in either boron or copper.

Corn leaves from research and demonstration plots analyzed at the Plant Analysis Laboratory in 1964 did not indicate a significant number of deficiencies of boron, copper, or zinc. The average contents of boron, copper, and zinc in the third leaf at tassel are shown by counties in Figures 1, 2, and 3. These average concentrations are considerably higher than known "critical" or deficiency concentrations (1, 5, 7).

This circular summarizes results of field experiments conducted to determine the effects of broadcast, pre-plant, and row applications of boron, copper, and zinc on leaf composition and yields of corn.

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PROCEDURES

Demonstration Plots, 1960-62

A series of demonstration plots was established in northwest Ohio between 1960 and 1962 with the cooperation of individual farmers and the Ohio Cooperative Extension Service. Non-replicated treatments of boron, copper, and zinc alone or in combination were applied to 21- by 60-foot plots established within production fields. The micronutrient fertilizers were supplied to cooperating farmers who broadcast and worked these into the soil prior to planting.

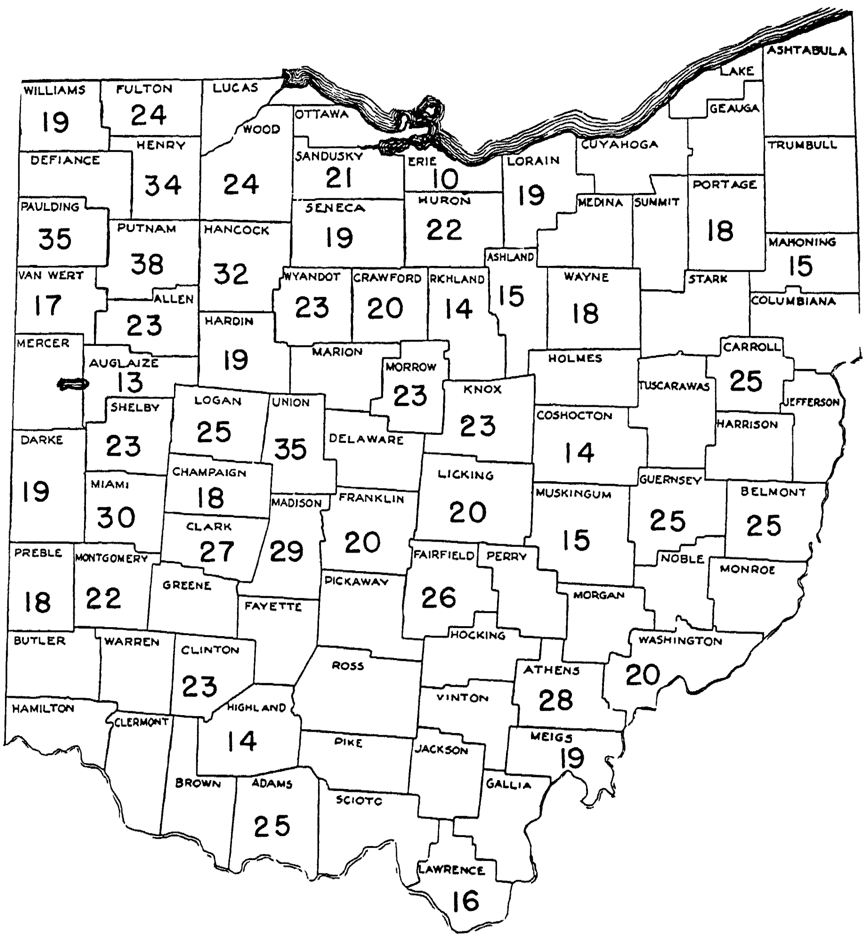

Fig. 1.—Typical boron content (ppm) in corn leaves sampled at tasseling, third leaf from tassel, 1964.

Experiments were conducted at three locations in 1960, nine in 1961, and 23 in 1962. The effects of treatments on grain yields were determined each year. Leaf samples for analyses were taken only in 1962. There were no significant effects of treatment on average yields (Table 1) or on yields when comparisons were made by yield levels (Table 2).

In 1962, the third leaf below the tassel was removed at silking from 20 plants in each demonstration plot. These leaf samples were analyzed by a direct reading emission spectrograph (6) for 16 elements, including

Fig. 2—Typical copper content (ppm) in corn leaves sampled at tasseling, third leaf from tassel, 1964.

boron, copper, and zinc. Treatment with boron resulted in a 46 percent increase in boron content, copper treatment a 7 percent increase in copper content, and zinc treatment a 26 percent increase in zinc content (Table 3). The increases in boron and zinc content were statistically significant ($P<.05$).

Research Plots, 1962-64

A number of replicated experiments were conducted at several locations of the Ohio Agricultural Research and Development Center from 1962 to 1964. The effects of row applications (applied at plant-

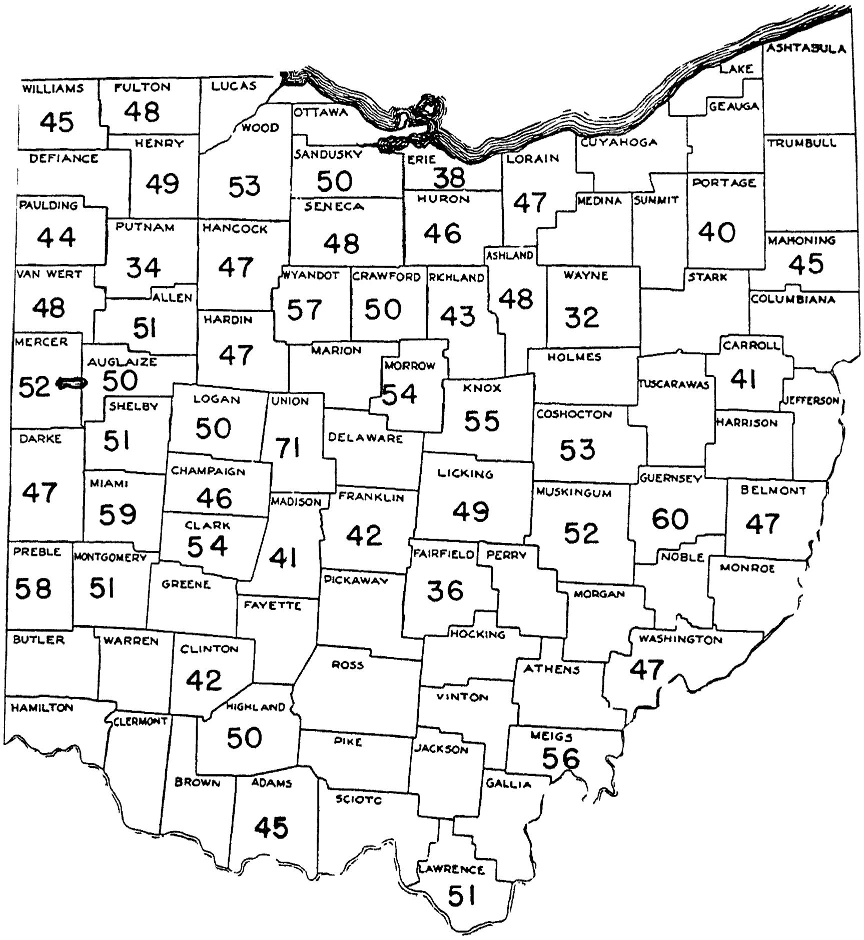

Fig. 3.—Typical zinc content (ppm) in corn leaves sampled at tasseling, third leaf from tassel, 1964.

TABLE 1.—Corn Yield as Affected by Applications of Boron, Copper, and Zinc to Soils of Northwest Ohio, 1960, 1961, and 1962.

Year	No. of Observations	Yield Bu./A. Check	Boron	Copper	Zinc
1960	3	109	105	105	113
1961	9	110	109	114	107
1962	23	100	97	100	100

All elements broadcast as:

Boron: 32 lb. borax (14.3% B) per acre.
Copper: 100 lb. copper sulfate (25.2% Cu) per acre.
Zinc: 100 lb. zinc sulfate (36% Zn) per acre.

TABLE 2.—Corn Yield as Affected by Applications of Boron, Copper, and Zinc at Three Yield Levels, Three Year Averages for 1960-62.

Yield Level Bu./A	Yield Check	Boron	Check	Copper	Check	Zinc
	Bu./A.		Bu./A.		Bu./A.	
less than 100	87	84	87	85	84	79
100-125	117	115	115	115	113	112
more than 125	137	137	131	137*	131	142*

All elements broadcast as:

Boron: 32 lb. borax (14.3% B) per acre.
Copper: 100 lb. copper sulfate (25.2% Cu) per acre.
Zinc: 100 lb. zinc sulfate (36% Zn) per acre.

*Not statistically different from check yield.

Table 3.—Average Boron, Copper, and Zinc Content of Corn Leaves from Micronutrient Demonstration Plots, Northwest Ohio, 1962.

Micronutrient Treatment	Leaf Composition† Boron	Copper	Zinc
	ppm	ppm	ppm
No micronutrients applied	28	14	58
Boron, 32 lb. Borax/A.	41*	14	60
No micronutrients applied	28	14	58
Copper, 100 lb. $CuSO_4 \cdot 5H_2O$/A.	28	15	58
No micronutrients applied	27	13	57
Zinc, 100 lb. $ZnSO_4 \cdot H_2O$	28	14	72*

*Difference statistically significant at the 5% level.
†Third leaf below the tassel when plants in silk.

Year	Location	Boron Source	Boron Rate	Copper Source	Copper Rate	Zinc Source	Zinc Rate
1962	All locations	Borate-46	¾ lb. B/A	None Applied		$ZnCO_3$	5 lb./A
1963	Mahoning and Snyder	Boric Acid	½ lb. B/A	$CuSO_4 \cdot 5H_2O$	5 lb./A	$ZnSO_4 \cdot H_2O$	10 lb./A
1963	Carpenter	Boric Acid	¼ lb. B/A	$CuSO_4 \cdot 5H_2O$	5 lb./A	$ZnSO_4 \cdot H_2O$	10 lb./A
1964	Western	Solubor (20% B)	¼ lb. B/A	$CuSO_4 \cdot 5H_2O$	5 lb./A	$ZnSO_4 \cdot H_2O$	10 lb./A
1964	Mahoning	None Applied		None Applied		$ZnSO_4 \cdot H_2O$	1, 2, 4, 8 lb. Zn/A
1964	Snyder	None Applied		None Applied		$ZnSO_4 \cdot H_2O$	1, 2, 4, 8 lb. Zn/A
1964	Snyder	None Applied		None Applied		ZnO	1, 2, 4, 8 lb. Zn/A
1964	Snyder	None Applied		None Applied		NuZn	1, 2, 4, 8 lb. Zn/A
1964	Snyder	None Applied		None Applied		Seq. Zn 450	1, 2, 4, 8 lb. Zn/A

Borate-46 and $ZnCO_3$ supplied by Landmark Farm Bureau Cooperative Association, Inc.
Nu-Zn supplied by Tennessee Corp.
Seq. Zn 450 supplied by Geigy Chemical Co.
$ZnSO_4 \cdot H_2O$ and ZnO supplied by Eagle-Picher Co.

ing) of boron, copper, and zinc alone and in combination on corn leaf composition and yields were studied.

Leaf samples were collected from all experiments and analyzed spectrographically (6) for boron, copper, and zinc contents. At each sampling date, 20 plants per plot were sampled. Time of leaf sampling varied with location and experiment. When the plants were about 3 feet high, the leaf immediately below the whorl was sampled. At the initiation of tasseling, the third leaf below the tassel was sampled.

At the Mahoning County Farm in 1964 (Table 11), the third leaf below the tassel at harvest was the only sample collected. The early sampling at the East Badger location in 1964 (Table 12) consisted of whole plants.

The rates of application and sources of materials were not the same each year. The choice of sources was based primarily on availability. The table on page 8 shows the materials and rates used at each location for each year.

At each location, sufficient quantities of NPK fertilizer were applied to insure against deficiencies of these elements.

Below normal precipitation at the Trumbull County Experiment Farm in 1962 (Table 5) and at the Mahoning County Farm in 1963 (Table 8) reduced yields and may have influenced the effects of the micronutrient treatments on yields.

RESULTS AND DISCUSSION

A summary of the results is shown in Table 4 and experimental results from each location are shown in Tables 5 through 12. These data show that applications of micronutrients did not significantly increase yields.

Since the copper treatments had no significant effects on corn leaf composition or yields, these data are not summarized in Table 4. They are shown in Tables 8, 9, 10, and 13.

Significant corn yield decreases of 8 to 30 bushels per acre occurred when boron was row applied at planting at rates of ¼ to ¾ lb. boron per acre. Corn is adversely affected by an excess of boron (2) and results from these experiments indicate that rates of ¼ lb. boron row applied per acre can significantly reduce corn yields.

At the Southeastern Branch (Table 7), plants on the Tilsit and Rardin soils appeared stunted when boron was applied at ¾ lb. per acre.

The boron content of the leaves in the early growth stage (3 to 4 feet tall) increased several times with boron treatment. The extent of increase varied with location and soil type (Table 4). The effects of

TABLE 4.—Summarization of Corn Yield Responses and Plant Composition Increases as Affected by Boron and Zinc Treatments at Each Location, 1962-1964.

Location/Year/ Hybrid or Soil Type	Micronutrient Source	Element Rate Applied	Yield Increase (+) or Decrease (—) Over Check	Increase in Element Concentration Over Check: Leaf Below Whorl	Increase in Element Concentration Over Check: Third Leaf Below Tassel
		Lb./A	%	%	%
		Boron Treatment			
Trumbull/62/K62	Borate-46	3/4	—32	nst*	45
Trumbull/62/M53	Borate-46	3/4	—14	nst	62
Mahoning/62/—	Borate-46	3/4	—6	560	27
Carpenter/62/Tilsit	Borate-46	3/4	—12	265	41
Carpenter/62/Rardin	Borate-46	3/4	—29	285	50
Carpenter/62/Meigs	Borate-46	3/4	0	186	8
Mahoning/63/—	Boric Acid	1/2	—9	106	nst
Carpenter/63/Tilsit	Boric Acid	1/4	—7	67	nst
Snyder/63/—	Boric Acid	1/2	—5	330	nst
Western/64/—	Solubor(20% B)	1/4	—10	nst	42
		Zinc Treatment			
Trumbull/62/K62	$ZnCO_3$	2.5	0	nst	5
Trumbull/62/K62	$ZnCO_3$	2.5	0	nst	0
Mahoning/62/—	$ZnCO_3$	2.5	0	0	0
Carpenter/62/Tilsit	$ZnCO_3$	2.5	—11	104	0
Carpenter/62/Rardin	$ZnCO_3$	2.5	—17	82	0
Carpenter/62/Meigs	$ZnCO_3$	2.5	0	0	0
Mahoning/63/—	$ZnSO_4 \cdot H_2O$	3.6	+15	27	nst
Carpenter/63/Tilsit	$ZnSO_4 \cdot H_2O$	3.6	0	54	nst
Snyder/63/—	$ZnSO_4 \cdot H_2O$	3.6	—7	109	nst
Western/64/—	$ZnSO_4 \cdot H_2O$	3.6	0	nst	22
Mahoning/64/—	$ZnSO_4 \cdot H_2O$	1	0	nst	8
Mahoning/64/—	$ZnSO_4 \cdot H_2O$	2	0	nst	13
Mahoning/64/—	$ZnSO_4 \cdot H_2O$	4	0	nst	30
Mahoning/64/—	$ZnSO_4 \cdot H_2O$	8	0	nst	39

*nst—no samples taken.

TABLE 4. (Continued)—Summarization of Corn Yield Responses and Plant Composition Increases as Affected by Boron and Zinc Treatments at Each Location, 1962-1964.

Location/Year/ Hybrid or Soil Type	Micronutrient Source	Element Rate Applied	Yield Increase (+) or Decrease (—) Over Check	Increase in Element Concentration Over Check: Leaf Below Whorl	Increase in Element Concentration Over Check: Third Leaf Below Tassel
		Lb./A	%	%	%
				Whole Plant	
Snyder/64/—	$ZnSO_4 \cdot H_2O$	1	0	44	14
Snyder/64/—	$ZnSO_4 \cdot H_2O$	2	0	55	7
Snyder/64/—	$ZnSO_4 \cdot H_2O$	4	0	80	19
Snyder/64/—	$ZnSO_4 \cdot H_2O$	8	0	106	40
Snyder/64/—	ZnO	1	0	12	0
Snyder/64/—	ZnO	2	0	22	10
Snyder/64/—	ZnO	4	0	25	0
Snyder/64/—	ZnO	8	0	44	17
Snyder/64/—	NuZn	1	0	23	7
Snyder/64/—	NuZn	2	0	22	0
Snyder/64/—	NuZn	4	0	53	7
Snyder/64/—	NuZn	8	0	69	33
Snyder/64/—	Seq. Zn 450	1	0	15	14
Snyder/64/—	Seq. Zn 450	2	0	42	21
Snyder/64/—	Seq. Zn 450	4	0	44	19
Snyder/64/—	Seq. Zn 450	8	0	69	24
		Boron and Zinc Treatment			
		B/Zn		**B/Zn**	**B/Zn**
Trumbull/62/K62	Borate-46/$ZnCO_3$	$\frac{3}{4}$/2.5	0	nst*	45/8
Trumbull/62/M53	Borate-46/$ZnCO_3$	$\frac{3}{4}$/2.5	—7	nst	52/0
Mahoning/62/—	Borate-46/$ZnCO_3$	$\frac{3}{4}$/2.5	0	610/0	92/0
Carpenter/62/Tilsit	Borate-46/$ZnCO_3$	$\frac{3}{4}$/2.5	—13	265/81	12/7
Carpenter/62/Rardin	Borate-46/$ZnCO_3$	$\frac{3}{4}$/2.5	—9	240/70	84/0
Carpenter/62/Meigs	Borate-46/$ZnCO_3$	$\frac{3}{4}$/2.5	0	230/12	0/0
Mahoning/63/—	Boric Acid/$ZnSO_4 \cdot H_2O$	$\frac{1}{2}$/3.6	0	160/0	nst
Carpenter/63/Tilsit	Boric Acid/$ZnSO_4 \cdot H_2O$	$\frac{1}{4}$/3.6	—7	58/37	nst
Snyder/63/—	Boric Acid/$ZnSO_4 \cdot H_2O$	$\frac{1}{2}$/3.6	0	33/150	nst

*nst—no samples taken.

treatment tended to decrease with time. By silking, the difference in boron content of leaves between the check and boron-treated plants was usually less than double.

Yield reductions occurred when boron concentrations in the leaves were in excess of 40 ppm during the early growth stage (3 to 4 feet tall) and 25 ppm in the third leaf at silking. Chapman (2) also found that 25 ppm boron was the minimum level in corn leaves associated with toxicity.

In the leaf analyses, boron concentrations in the third leaf at silking have frequently exceeded 25 ppm (see Figure 1). This indicates that boron toxicities may be widespread in Ohio and therefore the relation of boron content to yields should be studied in greater detail.

The effects of zinc treatments on leaf composition varied with sources and rates of application. Zinc carbonate ($ZnCO_3$) had little effect on leaf composition at two locations (Tables 5 and 6). At the Southeastern Branch (Table 7), zinc carbonate increased the zinc content of corn leaves removed when plants were 3 to 4 feet tall on the Tilsit and Rardin soils. At the later sampling when the plants were in silk, the zinc content of the third leaf was not affected by the zinc carbonate treatment.

TABLE 5.—Yield and Leaf Composition of Two Corn Hybrids (K62, M53) as Affected by Row Applications of Boron and Zinc, Trumbull County Experiment Farm, 1962.

Micronutrient Treatment	Yield Bu./A.	Leaf Composition‡ Boron ppm	Zinc ppm
	K62		
None applied	64	22	74
Boron*	44	32	76
Zinc†	64	22	78
Boron and Zinc*, †	59	33	80
	M53		
None applied	58	21	60
Boron*	50	34	60
Zinc†	55	24	62
Boron and Zinc*, †	54	32	60

*3/4 lb. B/A. as Borate-46
†5 lb. $ZnCO_3$/A.
‡Sampled 7/23/62, third leaf below the tassel when plants in silk.
Average leaf composition:
K62: K-1.8%, P-0.40%, Ca-0.50%, Mg-0.10%, Mn 80 ppm, Fe-100 ppm, Cu-9 ppm, Al-15 ppm.
M53: K-2.0%, P-0.52%, Ca-0.45%, Mg-0.14%, Mn-95 ppm, Fe-110 ppm, Cu-11 ppm, Al-15 ppm.

TABLE 6.—Corn Yield and Leaf Composition as Affected by Row Application of Boron and Zinc, Mahoning County Farm, 1962.

Micronutrient Treatment	Yield Bu./A.	Leaf Composition†† 6/19/62‡ Boron	Zinc	7/23/62** Boron	Zinc
		ppm	ppm	ppm	ppm
None Applied	82	11	48	15	52
Boron*	77	73	44	19	50
Zinc†	81	10	50	17	54
Boron and Zinc*, †	80	78	46	26	47

* ¾ lb. B/A. as Borate-46.
†5 lb. $ZnCO_3$/A.
‡Leaf immediately below whorl (corn approximately 2½ feet tall).
**Third leaf below the tassel when plants in silk.
††Average leaf composition:
6/19/62: K.3.5%, P-0.25%, Ca-0.45%, Mg-0.13%, Mn-250 ppm, Fe-200 ppm, Cu-15 ppm.
7/23/62: K-1.9%, P-0.26%, Ca-0.41%, Mg-0.12%, Mn-210 ppm, Fe-120 ppm, Cu-17 ppm.

Zinc sulfate ($ZnSO_4 \cdot H_2O$) was as effective as zinc carbonate in increasing the zinc content of the leaves at the early sampling date and was more effective at silking time (Table 4). Increasing the rate of application of zinc sulfate increased the zinc content of the leaves (Tables 11 and 12).

In a comparison of zinc sources (Table 12), zinc sulfate ($ZnSO_4 \cdot H_2O$) was most effective in increasing the zinc content of the whole plant and the third leaf at silk. NuZn and Seq. Zn 450 were less effective than zinc sulfate but more effective than zinc oxide (ZnO).

When boron and zinc were applied together, corn yields were usually significantly reduced. However, the degree of yield reduction in some instances was less than when boron was applied alone (Table 4). The effects of combining boron and zinc were not different than the effects of each element applied separately.

SUMMARY

The effects of boron, copper, and zinc fertilization on corn plant and leaf composition and yields were studied at several locations. No significant yield increases were obtained when each element was row applied singly or in combination.

Boron at rates of ¼ to ¾ lb. per acre significantly reduced corn yields. The boron and zinc contents of the corn plants and/or leaves were usually increased by the applications of boron and zinc, with the largest increase occurring during early growth. Copper treatment did not increase copper content of the corn leaves.

TABLE 7.—Corn Yield and Leaf Composition as Affected by Row Application of Boron and Zinc on Three Soil Types, Southeastern Branch, 1962.

Micronutrient Treatment	Yield Bu./A.	Leaf Composition 6/18/62‡ Boron	Leaf Composition 6/18/62‡ Zinc	Leaf Composition 7/19/62** Boron	Leaf Composition 7/19/62** Zinc
		ppm	ppm	ppm	ppm
		Tilsit Silt Loam			
None Applied	91	14	26	17	54
Boron*	80	61	25	24	54
Zinc†	80	14	53	14	52
Boron and Zinc*, †	79	63	47	19	58
		Rardin Silt Loam			
None Applied	103	14	23	12	60
Boron*	73	54	26	18	57
Zinc†	85	13	42	12	60
Boron and Zinc*, †	94	48	38	22	63
		Meigs Silty Clay Loam			
None Applied	108	14	34	12	61
Boron*	109	40	32	13	60
Zinc†	107	15	34	12	62
Boron and Zinc*, †	109	46	38	13	58

* ¾ lb. B/A. as Borate-46.
†5 lb. $ZnCO_3$/A.
‡Top fully emerged leaf (corn approximately 3 ft. tall).
**Third leaf below the tassel when plants in silk.

Average leaf composition, 6/18/62:

Tilsit: K-2.0%, P-0.48%, Ca-0.48%, Mg-0.26%, Mn-160 ppm, Fe-240 ppm, Cu-12 ppm
Rardin: K-1.9%, P-0.30%, Ca-0.50%, Mg-0.30%, Mn-115 ppm, Fe-370 ppm, Cu-15 ppm.
Meigs: K-2.1%, P-0.30%, Ca-0.40%, Mg-0.20%, Mn-115 ppm, Fe-240 ppm, Cu-14 ppm.

Average leaf composition, 7/19/62:

Tilsit: K-1.1%, P-0.39%, Ca-0.80%, Mg-0.32%, Mn-130 ppm, Fe-80 ppm, Cu-10 ppm.
Rardin: K-1.1%, P-0.41%, Ca-0.80%, Mg-0.40%, Mn-110 ppm, Fe-120 ppm, Cu-11 ppm.
Meigs: K-1.4%, P-0.37%, Ca-0.80%, Mg-0.35%, Mn-120 ppm, Fe-100 ppm, Cu-17 ppm.

TABLE 8.—Corn Yield and Leaf Composition as Affected by Row Applications of Boron, Copper, and Zinc, Mahoning County Farm, 1963.

Micronutrient Treatment	Yield Bu./A.**	Leaf Composition†† Boron	Copper	Zinc
		ppm	ppm	ppm
None Applied	67	17	13	45
Boron*	61	35	13	42
Copper†	66	16	13	40
Zinc‡	77	13	14	57
Boron, Copper, and Zinc*, †, ‡	66	27	14	45

* ½ lb. B/A as boric acid.
†5 lb. $CuSO_4 \cdot 5H_2O$ per acre.
‡10 lb. $ZnSO_4 \cdot H_2O$ per acre.
**Lower yields due to below average seasonal moisture. Yields were not significantly different.
††Leaf immediately below whorl (corn approximately 3 feet tall), 7/1/63.
Average leaf composition:
K-2.2%, P-0.30%, Ca-0.30%, Mg-0.15%, Mn-210 ppm, Fe-305 ppm, Al-120 ppm.

TABLE 9.—Corn Yield and Leaf Composition as Affected by Row Applications of Boron, Copper, and Zinc, Snyder Location, 1963.

Micronutrient Treatment	Yield Bu./A.	Leaf Composition** K	P	Ca	Mg	Mn	Fe	B	Cu	Zn
		%				ppm				
None Applied	110	1.98	.27	.50	.34	148	230	11	8	23
Boron*	105	2.10	.28	.47	.31	144	231	48	9	28
Copper†	109	2.07	.27	.48	.30	148	209	11	9	25
Zinc‡	102	1.93	.29	.47	.31	174	228	10	9	48
Boron, Copper, and Zinc*, †, ‡	104	2.12	.26	.49	.28	190	273	47	10	58

* ½ lb. boron per acre as boric acid.
†5 lb. $CuSO_4 \cdot 5H_2O$ per acre.
‡10 lb. $ZnSO_4 : H_2O$ per acre.
**Fully emerged leaf below the whorl sampled when the plants were approximately 3 feet tall, 7/3/63.

TABLE 10.—Corn Yield and Leaf Composition as Affected by Row Application of Boron, Copper, and Zinc, Southeastern Branch, 1963.

Micronutrient Treatment	Yield Bu./A.	Leaf Composition** Boron ppm	Copper ppm	Zinc ppm
None Applied	87	12	9	24
Boron*	81	20	9	26
Copper†	88	12	11	25
Zinc‡	86	11	9	37
Boron and Zinc*, ‡	81	19	8	35
Boron, Copper and Zinc*, † ‡	86	18	11	29

* ¼ lb. B/A. as boric acid.
†5 lb. $CuSO_4 \cdot 5H_2O$/A.
‡10 lb. $ZnSO_4 \cdot H_2O$/A.
**Fully emerged leaf below the whorl sampled when the plants were approximately 3 feet tall 6/18/63.
Average Composition: K-2.5%, P-0.30%, Ca-0.48%, Mg-0.20%, Mn-180 ppm, Fe-230 ppm, Al-200 ppm.

TABLE 11.—Corn Yield and Zinc Composition of Corn Leaves as Affected by Rate of Row Applied Zinc, Mahoning County Farm, 1964.

Treatment Lb. Zn/A.*	Yield Bu/A.	Leaf Composition Zn, ppm†
none	105	91
1	104	99
2	104	104
4	110	121
8	106	130

*As $ZnSO_4 \cdot H_2O$.
†Third leaf below tassel at harvest, 9/18/64.

TABLE 12.—Corn Yield and Zinc Plant and Leaf Concentrations as Affected by Row Applications of Zinc at Four Rates Using Four Sources, East Badger Location, 1964.

Treatment			Zinc Concentration, ppm	
Rate Lb. Zn/A.	Source	Yield Bu./A.	Whole Plant 6/22/64†	Third Leaf at Tassel‡
None Applied		117	36	42
1	NuZn	116	44	45
1	Seq. Zn 450	113	41	48
1	Zn O	116	40	39
1	$ZnSO_4 \cdot H_2O$	122	51	48
	mean	118	44	45
2	NuZn	114	42	43
2	Seq. Zn 450	119	51	51
2	Zn O	120	42	47
2	$ZnSO_4 \cdot H_2O$	119	56	46
	mean	118	48	47
4	NuZn	108	55	45
4	Seq. Zn 450	117	52	50
4	Zn O	117	45	45
4	$ZnSO_4 \cdot H_2O$	116	65	50
	mean	114	54	48
8	NuZn	120	61	56
8	Seq. Zn 450	116	61	52
8	Zn O	116	52	49
8	$ZnSO_4 \cdot H_2O$	119	74	59
	mean	118	62	54

*NuZn, 52% Zn, Tennessee Corp. Seq. Zn 450, 6.3% Zn, Geigy Chemical Co. Zn O, 67% Zn, Eagle-Picher Co. $ZnSO_4 \cdot H_2O$, 36% Zn, Eagle-Picher Co.

†Average plant composition: K-1.8%, P-0.33%, Ca-0.37%, Mg-0.21%, Mn-125 ppm, Fe-105 ppm, B-25 ppm, Cu-9 ppm.

‡Average leaf composition: K-1.9%, P-0.35%, Ca-0.48%, Mg-0.30%, Mn-100 ppm, Fe-90 ppm, B-16 ppm, Cu-12 ppm

TABLE 13.—Corn Yield and Leaf Composition as Affected by Row Applications of Boron, Copper, and Zinc, Western Branch, 1964.

Micronutrient Treatment	Yield Bu./A.	K (%)	P (%)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	B (ppm)	Cu (ppm)	Zn (ppm)
		Composition of Third Leaf*								
None Applied	83	2.37	.31	.36	.32	61	138	14	12	35
Boron†	75	2.27	.32	.41	.37	65	148	24	14	38
Copper‡	86	2.32	.31	.37	.34	64	145	14	13	37
Zinc**	85	2.26	.32	.43	.36	68	158	15	13	43

*Sampled at tasseling.

†1/4 lb. B/A as solubor (20% B).

‡5 lb. $CuSO_4 \cdot 5H_2O$/A.

**10 lb. $ZnSO_4 \cdot H_2O$/A.

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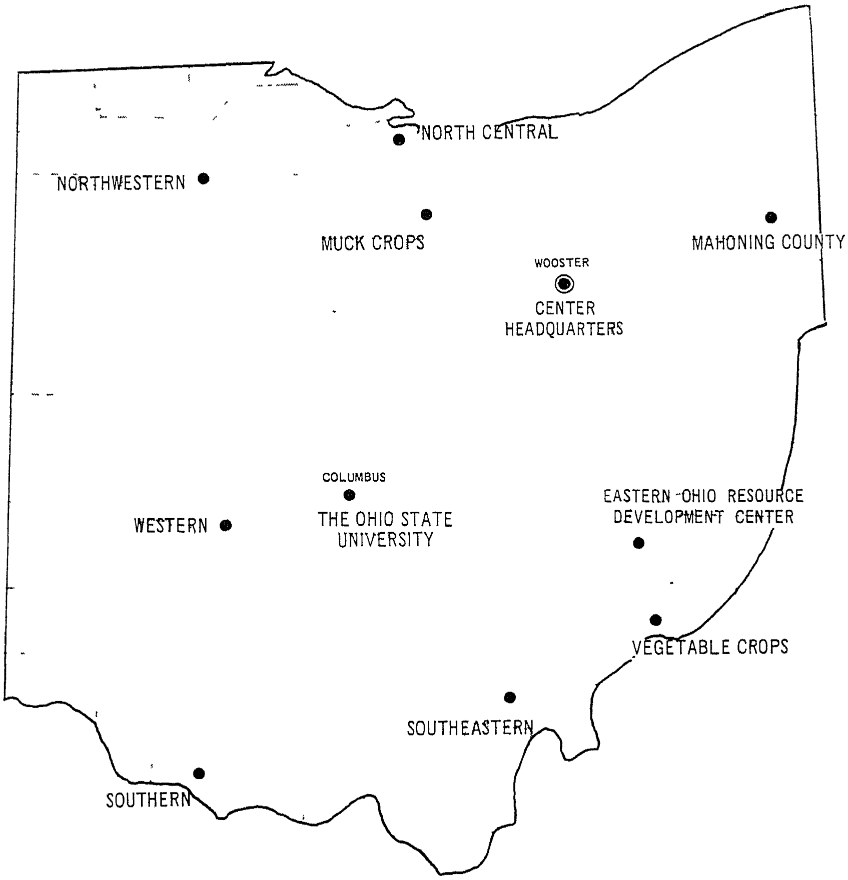

Ohio's major soil types and climatic conditions are represented at the Research Center's 11 locations. Thus, Center scientists can make field tests under conditions similar to those encountered by Ohio farmers.

Research is conducted by 14 departments on more than 6000 acres at Center headquarters in Wooster, nine branches, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 2017 acres
Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres
Mahoning County Experiment Farm, Canfield: 275 acres
Muck Crops Branch, Willard, Huron County: 15 acres
North Central Branch, Vickery, Erie County: 335 acres
Northwestern Branch, Hoytville, Wood County: 247 acres
Southeastern Branch, Carpenter, Meigs County: 330 acres
Southern Branch, Ripley, Brown County: 275 acres
Vegetable Crops Branch, Marietta, Washington County: 20 acres
Western Branch, South Charleston, Clark County: 428 acres